SCIENCE FOR GLASS PRODUCTION

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THE TREND TOWARD DEVELOPMENT OF TANK FURNACES IN PRODUCTION OF SHEET GLASS

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The cardinal changes in the design of sheet glass tank furnaces that significantly improve the technical and economic indexes are examined. The most effective technical solutions are the change in the design of the feed pocket, burners, regenerators, and knuckle and equipping them with modern process equipment and highly stable refractories.

The design of tank glass-making furnaces for sheet glass is relatively conservative. For the last 130 years, these Siemens furnaces have remained direct-flow regenerative furnaces with a transverse flame and end loading of batch and cullet. Moreover, the basic technical and economic indexes of their operation changed very significantly: unit capacity, specific takeoff of glass melt from the melting part of the furnace, and the duration of the run increased, while specific fuel consumption decreased by more than tens of times and the glass melt utilization factor increased from 0.30 – 0.40 to 0.85 – 0.90.

These cardinal changes were possible because of the improvement in the design of the most important furnace elements and the process conditions of operating the furnace. The important changes in the design of the float glass furnace over the past 20 – 30 years, especially in recent years, that most significantly increased its operating efficiency, are examined here. We also note that these changes are widely used by almost all of the companies that design such furnaces (HENRY TEICHMANN and TECO in the USA, HORN, SORG, and STEIN HEURTEY in Europe, and many others).

Let us begin with the unit for loading the batch and cullet into the furnace.

First, it became frontal (equal to the width of the melting tank even when the width increased to 12 – 13 m), which restricts the melting zone to the region of the first – beginning of the second pair of burners.

Second, it is usually equipped with an end wall designed by MERKLE, USA, in the gas space (Fig. 1). The combination of different refractories — mullite, zirconium-mullite, and Dinas compositions — as a function of the conditions of servicing the individual wall sections with the optimum configuration and use of several rows of suspended thermostable refractory tiles that overlap the pocket create conditions for preliminary surface melting of batch heaps, reducing entrainment of dust into the regenerator packing.

Third, the pockets are equipped with wide steel batch and cullet chargers and form an almost continuous (with no interruptions) pile load over the entire width of the pocket, which accelerates the initial stages of the melting process.

Modern furnaces are equipped with efficient fuel burning systems with accurate fixation and automatic regulation of flow in the individual nozzles and automatic regulation of air

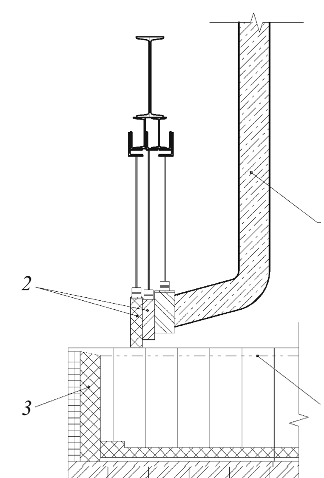

Fig. 1. End wall of Merkel design feed pocket: *1*) wall directly; *2*) suspended refractory tiles; *3*) feed pocket end wall; *4*) glass melt surface level.

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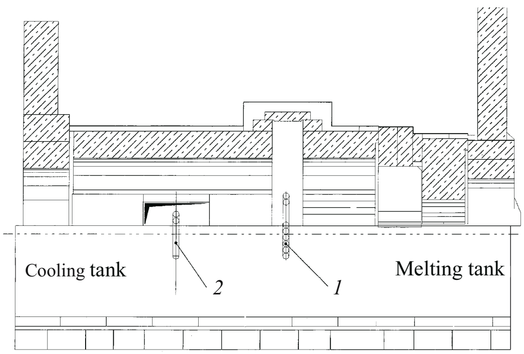

Fig. 2. Diagram of knuckle design: *1*) air-cooled barrier condenser; *2*) horizontal stirrer.

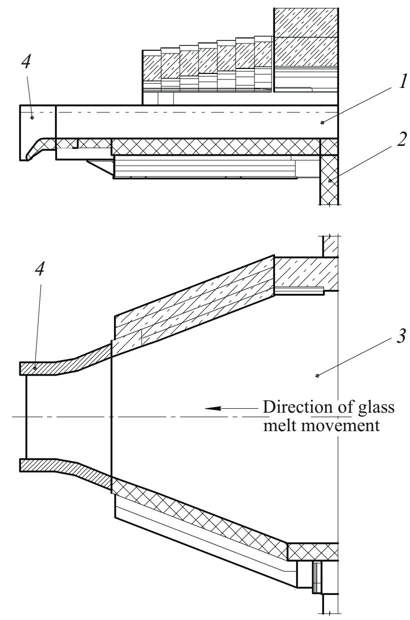

Fig. 3. Most common discharge channel design: *1*) trapezoidal discharge channel; *2*) end wall of cooling tank; *3*) glass melt surface level; *4*) discharge unit.

flow, which stabilizes the excess air coefficient and ensures the required length (without overshooting) and flare luminance and allows precisely maintaining the given glass melting temperature conditions. We note that fuel is burned both by lower feed — under the burner mouth (basically in Europe), and side feed — through the side walls of the burners (USA).

Gas-oxygen furnaces are becoming increasingly widespread; high thermal efficiency (up to 70 – 80%) and the almost total absence of harmful nitrogen oxides in the stack gases are characteristic of them, which eliminates environmental pollution.

An important factor in increasing the technical and economic indexes of furnace operation is optimizing the size of the regenerators. Increasing the size (especially the height) of the checker packing in the regeneration chambers while maintaining the required packing proportion factor packing lining with cup or cruciform packing will ensure the maximum thermal efficiency of the regeneration cycle. This is also confirmed by the significantly increasing air-heating temperature (to 1400 – 1450°C) and the important decrease in the stack gas temperature on leaving the packing (450 – 500°C). Despite the severe temperature conditions of use of the packing in conditions of constant heat circulation, they are currently used during the entire furnace run, eliminating the need for conducting material- and labor-intensive repairs for periodic replacement of worn packing. It should be noted that regenerators with no separating walls are used in many float-glass furnaces, especially in the USA, and this additionally increases their thermal efficiency by 10 – 15%.

Complete thermal insulation of the outside of the lining is the next important factor that both decreases fuel consumption and improves the conditions of servicing the refractory lining of the furnace. Different methods of insulating the individual furnace elements in mandatory conditions of sealing the lining and eliminating the possibility of any contact reaction between the refractories and insulating materials used have been developed in recent years.

So-called two-layer basic and additional insulation is frequently used in insulating the bottom of the melting tank, which allows conducting melting in the furnace for both colorless and colored sheet glass during one run. We note that thermally insulating this element increase the temperature of the inner surface of the floor to 1250 – 1300°C. The possibility of formation of a supercooled ("dead") near-bottom layer of glass melt is totally excluded here, and the neutralizing power of the furnace and quality of the processed glass increase significantly. A device in float-glass furnaces for heating part of the hot conditioning zone (called the refining zone abroad), which occupies up to 40% of the melting or 80% of the heating part of the furnace, produces the same results. The concluding stages of clarification and high-temperature neutralization that take place in this zone are very important for entry of high-quality glass melt in molding.

The knuckle design (Fig. 2) is optimized. As a result of many studies, it was made narrow (30 – 35% of the width of the melting tank) and short (5.0 – 5.5 m), sufficient for positioning the air-cooled barrier condenser and horizontal mixer.

The area of the cooling part was significantly decreased (by 30 – 40%), which reduces the backflow and convection currents that worsen the homogeneity of the glass melt. When cooling potential is lacking and for accurately maintaining the temperature in the production channel, an automated system for feeding cold air in the gas space of the cooling part of the furnace is widely used.

The design of the discharge channel was optimized (Fig. 3), which eliminated possible worsening of the quality of the glass melt in the concluding stage before discharge and subsequent molding of the glass ribbon.

Total automation and computerization of all stages of the manufacturing process unconditionally results in stability of the basic furnace parameters and the manufacturing conditions as a whole. We should also emphasize the positive effect of the universal and wide use of highly stable, quality manufactured refractories and heat insulating materials and articles on all technical and economic indexes of float-glass furnaces.

Refractories manufactured by the leading world companies: SEFPRO (France), RHI and VESUVIUS (Germany), and MOTIM (Hungary) are basically used for building float-glass furnaces. Many of the successfully developed Chinese refractory companies, especially the products sold by KROK Co. on the Russian market, can be included in the leading firms with total justification.

When these and other effective technical solutions were implemented, float-glass tank furnaces from the leading world firms presented high performance indexes in subsequent years: specific takeoff of glass melt from the melting part of the furnace of 2200 – 2500 kg/m^2 a day, specific heat flow for glass melting of 5850 – 6070 kJ/kg; number of flaws in glass ribbon of 0.5 – 1.0 per ton of finished product, and 80% yield of high-quality glass at the minimum.

The first reconstruction of furnace No. 1 for polished sheet glass after startup in 1975 was conducted in 1992 with partial implementation of the technical solutions developed at Salavatsteklo works and reported here (increasing the packing volume, creating a hot conditioning zone, ensuring complete thermal insulation of the melting part, including insulating the floor of the melting tank, and decreasing the area of the knuckle and cooling part). This allowed significantly improving the technical and economic operating indexes, in particular, decreasing the specific heat flow for melting by 20%, eliminating use of additional electric heating of the glass melt in the melting and quell point regions without increasing gas flow in the furnace, and increasing the quality of the glass processed.

Reconstruction of float-glass systems Nos. 1 and 2 conducted in 2005 and 2007 and operation of the furnaces after completion of the reconstruction work allowed not only increasing the production capacities by more than 1.5 times but also ensured attaining the indexes of the leading world companies reported above.